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Crop Sequence and No-Till Reduce Seedling Emergence of Common Sunflower (*Helianthus annuus*) in Following Years

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Weed management is evolving to include cultural tactics that reduce weed populations. This study near Brookings, SD, evaluated the effect of crop sequence and tillage on seedling emergence of common sunflower across years. In the third and fourth years of the study, seedling density was sevenfold greater after 2 yr of soybean with tillage compared with a 2-yr sequence of canola and winter wheat with no-till. Apparently, canola and winter wheat enhanced the natural decline of common sunflower seed density in soil, leading to fewer seedlings in following years. In the first year of the study, tillage increased seedling emergence of common sunflower compared with no-till; seedlings rarely emerged in canola or winter wheat. Most seedlings of common sunflower emerged in May, with more than 90% of seedlings emerging between May 7 and June 4. Cool-season crops grown with no-till may affect weed seed survival in soil in the western Corn Belt.
Nomenclature: Common sunflower, *Helianthus annuus* L. HELAN; canola, *Brassica napus* L.; soybean, *Glycine max* (L.) Merr.; winter wheat, *Triticum aestivum* L.
Key words: Crop diversity, rotation design, weed seed survival.

Common sunflower is prominent in the western Corn Belt, readily establishing in both corn (*Zea mays* L.) and soybean, and can drastically reduce yields, especially that of soybean. For example, 1 plant/m^2 reduced soybean yield 35 to 45% when emerging with the crop in Kansas (Geier et al. 1996), whereas in Missouri, 3 plants/m^2 reduced soybean yield 47 to 72% (Allen et al. 2000). Herbicides are available to control common sunflower, but producers are seeking to reduce costs of weed management by using cultural tactics to reduce weed density in their crops.

One cultural tactic to reduce weed density is growing cover crops such as rye (*Secale cereale* L.) (Teasdale 1996). Cover crops suppress germination and seedling establishment of weeds by allelopathy or altered environmental conditions. The mulch also physically impedes the establishment of weed seedlings.

Another tactic is to diversify the corn–soybean rotation with cool-season crops, such as winter wheat. Crops with different life cycles provide more opportunities for producers to control weeds before seeds are produced (Froud-Williams 1988). Thus, seed production of warm-season weeds can usually be eliminated during the years of cool-season crops, with similar control of cool-season weeds occurring during years of warm-season crops. By preventing replenishment of the seed bank, the natural decline of weed seed density in soil across time reduces the number of seedlings emerging in later crops.

Cover crops and cool-season crops may help producers manage common sunflower during the current crop season, but we wondered if suppressing seedling emergence with cover crops may lead to more common sunflower seedlings in following years. Our reasoning for this concern is based on results by Egley and Williams (1990), who compared seedling emergence across time of several weed species among various cultural treatments. They noted a trend across all species; treatments with less seedling emergence in the first year had more seedlings in following years. We also questioned whether cool-season crops grown for grain would suppress seedling emergence of common sunflower, leading to more seedlings in following years.

Furthermore, producers are reducing tillage intensity to minimize costs and preserve soil health. Less tillage may prolong seed survival of common sunflower in the seed bank. Froud-Williams et al. (1984) found that density of viable weed seeds of several species in soil declined more rapidly when soil was tilled several times compared with no-till (NT). Studies in Minnesota showed a similar trend with survival of both velvetleaf (*Abutilon theophrasti* Medik.) and wild mustard [*Brassica kaber* (DC.) L.C. Wheeler] being greater across years with NT compared with a tilled system (Lueschen and Andersen 1980; Warnes and Andersen 1984).

Cropping systems studies in the semiarid Great Plains, however, have shown that the impact of tillage on weed community dynamics may be related to rotation design (Anderson 2005). Weed community density declined across time with NT when rotations consisted of two cool-season crops followed by two warm-season crops; in contrast, weed community density was 13-fold greater with a two-crop rotation and NT. Tillage lessened the impact of rotation design on weed community density; with four-crop rotations, tillage increased weed community density sixfold compared to NT.

Common sunflower seed can persist in soil for 3 to 5 yr (Burnside et al. 1981; Snow et al. 1998). Therefore, we conducted this experiment to determine whether cool-season crops and seedbed preparation affect seedling emergence of common sunflower across time. A second goal was to quantify the seasonal emergence pattern of common sunflower.

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Table 1. Cultural treatments related to seedling emergence of common sunflower.[a]

Treatment	Tillage[b]	Crop Sequence			
		Year 1	Year 2	Year 3	Year 4
1	CT	SB	SB	SB–NT	SB–NT
2	NT	SB	SB	SB	SB
3	NT	RSB	RSB	SB	SB
4	NT	W	SB	SB	SB
5	NT	Can	W	SB	SB

[a] Abbreviations: Can, canola; CT, conventional tillage; NT, no-till; RSB, rye as a cover crop with soybean; SB, soybean; W, winter wheat.

[b] Treatment 1 consisted of conventional tillage in years 1 and 2, followed by no-till in years 3 and 4; the remaining treatments were no-till in all years.

Materials and Methods

Site Characteristics. The 4-yr experiment was established in the fall of 2000 near Brookings, SD. The experiment was repeated at an adjacent site during 2001 to 2005. The soil was a Barnes clay loam (Calcic Hapludolls) with approximately 3% organic matter and a pH ranging from 6.8 to 7.2. Average precipitation (84-yr record) is 537 mm, with May and June receiving the highest rainfall. The two study sites, naturally infested with common sunflower, were established in spring wheat stubble. Previous to spring wheat, the cropping history of the sites was corn–soybean.

Cultural Treatments and Study Design. A series of cultural treatments were established across a 4-yr period (Table 1). In the first year, soybean was established in two treatments that compared tillage management. One treatment consisted of conventional tillage (CT) with chisel plowing in October of the previous fall, followed by disking in early May to prepare a seedbed, whereas the second treatment was NT, where glyphosate controlled weeds before planting. A third treatment was composed of NT with winter rye planted as a cover crop in early October of the previous year, then controlled with glyphosate at soybean planting. Treatments 4 and 5 were also NT, but planted either to winter wheat in September of the previous fall or canola in early April. The rate of glyphosate for all applications was 0.8 kg ae/ha.

In the second year, treatments 1, 2, and 3 were repeated, whereas soybean was planted in winter wheat stubble for treatment 4 (Table 1). For treatment 5, winter wheat was planted in canola stubble. In years 3 and 4, soybean was planted uniformly across all treatments with NT. Soybean was planted between May 15 and May 22.

The experimental design was a randomized split block with four replications. Whole plot size was 3 by 20 m. In the center 3- by 7-m area of each plot, any common sunflower plants were removed by hand to prevent seed being added to this subplot for the 4-yr interval of the study. The subplots within each whole plot were separated by a 1-m-wide, tilled, plant-free strip maintained during the cropping season.

Crop Management. Crops were established with practices commonly used in the region (Table 2). All crops were planted with a disk drill at a row spacing of 19 cm. With winter wheat and canola, starter fertilizer of 7 kg N + 20 kg P/ha in a dry formulation was banded with the crop row. Additional N fertilizer for winter wheat and canola was applied broadcast during the tillering and rosette growth stages, respectively, with the N level based on target-yield goals. A starter fertilizer for soybean, 7 kg N + 21 kg P + 7 kg K/ha, was applied in a liquid formulation between every other planted row, with *Rhizobium* spp. in a granular formulation applied with the soybean seed to facilitate N_2 fixation. In the weed-free subplot, common sunflower and other weeds were controlled with glyphosate applications and hand-weeding in soybean, whereas weeds were removed by hand in canola and winter wheat. Rye was in the early boot stage when terminated with glyphosate and left 2,200 to 2,500 kg/ha of biomass (dry weight) on the soil surface.

Seedling Emergence Measurements. Seedling emergence of common sunflower was recorded in the first year of each study in two 0.5-m^2 quadrats, one quadrat randomly located in each of the two weed-infested subplots. Counts were started in April and continued weekly throughout the growing season. We did not record seedling emergence in the second year because seed shedding from varying densities of common sunflower confounded treatment effects in infested subplots in the second year. Because of the high density of common sunflower in the weed-infested subplots, they were mowed in August to prevent spread of common sunflower seeds to the weed-free subplots.

To estimate the impact of cultural treatments on seedling recruitment across time, the number of common sunflower seedlings emerging in the 3- by 7-m weed-free subplot was recorded weekly in the third and fourth year of the study. After counting, seedlings were removed by hand.

Statistical Analysis. Data for all studies were analyzed by ANOVA. Initial analysis with the first year assessment indicated that an interaction between treatments and sites did not occur; therefore, treatment data were averaged across sites. With seedling emergence data in years 3 and 4, an interaction between treatments, years within a study, and sites did not occur; therefore, treatment data were averaged across years and sites. With all measurements, differences among treatment means were determined with Fisher's protected LSD at the 0.05 level of probability.

A seedling emergence pattern for common sunflower during the growing season was calculated by converting the

Table 2. Management practices for various crops grown in the study.

Crop	Cultivar	Planting date range	Seeding rate (plants/ha)	Fertilizer
Soybean	'Wensman 2198 RR'	May 15 to 22	360, 000	Starter
Winter rye	'Land race'	October 1 to 5	2 million	None
Winter wheat	'Crimson'	September 10 to 15	1.8 million	Starter + broadcast
Canola	'Invigor 2573 LL'	April 1 to 5	1.3 million	Starter + broadcast

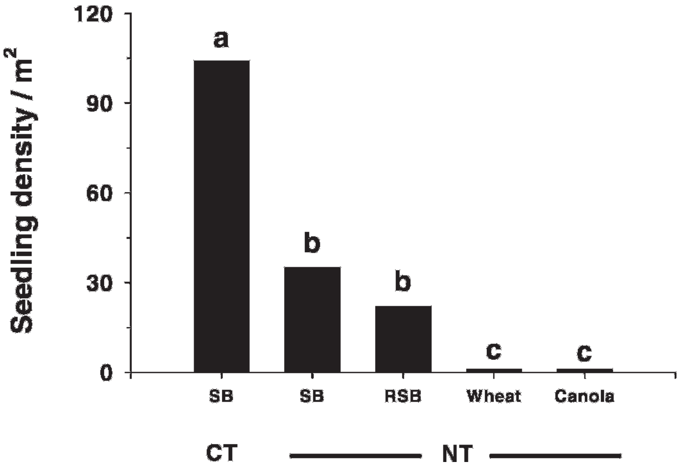

Figure 1. Density of common sunflower seedlings among five cultural treatments (CT, conventional tillage; NT, no-till; SB, soybean; RSB, rye as a cover crop with soybean) in the first year of the study (data were averaged across two sites; bars with the same letter are not significantly different as determined by Fisher's protected LSD [0.05]).

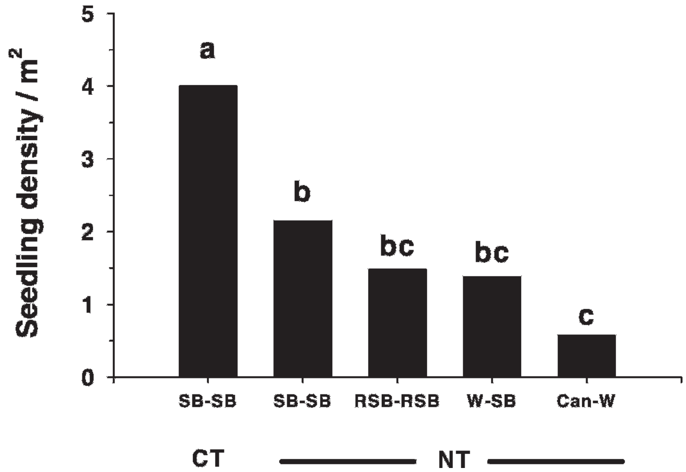

Figure 2. Cumulative seedling emergence of common sunflower in years 3 and 4 (averaged) in the 21-m^2 weed-free subplot as affected by crop sequence (years 1 and 2 indicated on x-axis; SB, soybean; RSB, rye as a cover crop with soybean; W, winter wheat; Can, canola) and tillage (CT, conventional tillage; NT, no-till) (data were averaged across sites; bars with the same letter are not significantly different as determined by Fisher's protected LSD [0.05]).

seedling density per week of the CT, NT, and rye cover crop treatments to a percentage of seasonal emergence and averaging the data for a yearly pattern. A composite emergence pattern was developed by averaging emergence data from the first, third, and fourth year of each site. The final emergence curve was developed by cubic spline interpolation.[1]

Results and Discussion

Impact of Cultural Tactics on Seedling Emergence in the First Year. Seedling density was highest after tillage, with 104 plants/m^2; in contrast, seedling density in NT plots was 35 plants/m^2 or 66% less compared with CT (Figure 1). Including a rye cover crop with no-till did not further reduce seedling emergence of common sunflower compared with the NT treatment. Common sunflower seedlings were rarely observed in either canola or winter wheat, which we attribute to the canopies of these crops providing an unfavorable microenvironment for common sunflower germination and emergence.

Seedling Emergence in the Third and Fourth Years. With CT, 4 seedlings/m^2 emerged during the cropping seasons of years 3 and 4 (Figure 2). In contrast, only 0.6 seedlings emerged in plots following the canola–winter wheat sequence, a sevenfold difference when compared with the CT system. With NT, 2.1 seedlings/m^2 emerged, a decline of 48% compared with CT. Seedling density did not differ between NT and treatments including rye as a cover crop preceding soybean or a winter wheat–soybean sequence.

The trend with fewer seedlings following the canola–winter wheat sequence, even though few seedlings emerged during the growing seasons of canola and winter wheat, differs with results observed by Egley and Williams (1990). In their study, seedling emergence of several weeds in later years was related to initial emergence; high emergence in the first year led to fewer seedlings in following years. This contrast in results, however, may reflect differences in methodology among studies; in Egley and Williams (1990), cultural treatments did not include the presence of crops. In our study, the presence of crops may have altered seed-bank dynamics with NT. In addition, the studies by Froud-Williams et al. (1984), Lueschen and Anderson (1980), and Warnes and Andersen (1984), cited earlier, did not include the presence of crops in their treatments.

Weed seeds in soil can experience a multitude of possible fates, such as germination, death due to environmental exposure, natural decay, or predation by fauna and micro-organisms (Harper 1977). In our study, maintaining weed seeds on the soil surface with NT and following a sequence of canola and winter wheat apparently provided an environment that was less favorable to seed survival and subsequent seedling emergence. The lack of seed burial with NT may favor loss of seed viability because of exposure to environmental extremes (Lonsdale 1993; Sagar and Mortimer 1976), whereas the crop sequence effect may be related to microbial dynamics. Kennedy and Kremer (1996) suggested that weed-seed decay may be enhanced by NT systems that concentrate weed seeds near the soil surface where microbial activity and organic matter are highest in the soil profile. Also, the dense canopies of canola and winter wheat during the high rainfall period of May and June may have led to a microenvironment near the soil surface more favorable to microbial decay and arthropod predation.

Seedling Emergence Pattern of Common Sunflower. Knowledge of weed emergence patterns can guide culturally based control strategies, such as varying planting dates or crop choices. Averaged across 5 yr, seedlings emerged primarily in May; more than 90% of seedlings emerged between May 7 and June 4 (Figure 3). Emergence peaked on May 21, and seedlings were not observed after June 18.

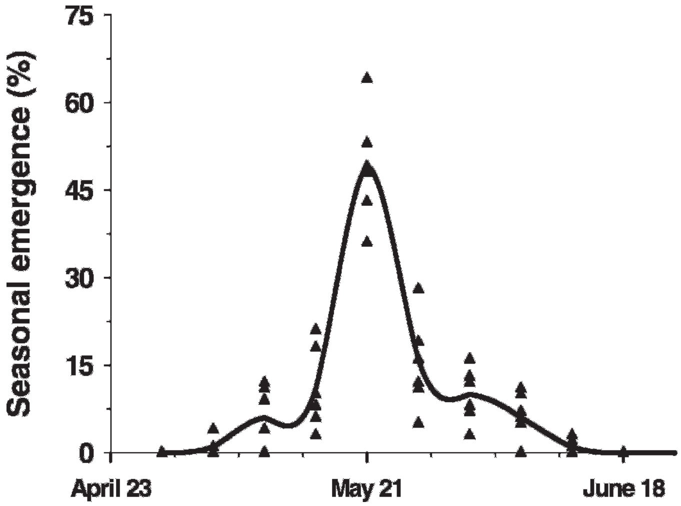

Figure 3. Emergence pattern of common sunflower, averaged across 3 yr and two sites (triangles represent weekly seasonal emergence means for each of the six site–years).

Implications for Weed Management. Weed management is changing to include strategies to reduce weed community density in addition to control tactics (Mortensen et al. 2000). Our study showed that cool-season crops grown with NT may accelerate the natural decline of seed bank density of common sunflower. Seedling density was reduced 86% following a sequence of canola–winter wheat with NT compared with 2 yr of soybean and tillage.

The benefit of rotating crops with different life cycles for weed management has been attributed to eliminating seed production of weeds during some years of the rotation (Froud-Williams 1988). We suggest that the presence of cool-season crops may also affect weed dynamics by influencing weed seed survival in soil. If this impact of cool-season crops on common sunflower seedling emergence should occur with other warm-season weeds, producers in the western Corn Belt may be able to reduce the need for herbicides. In the semiarid Great Plains, producers who rotated cool-season and warm-season crops reduced weed community density and could grow some crops without needing herbicides to achieve optimum yields (Anderson 2005). With these diverse rotations, producers are using 50% less herbicide to manage weeds compared with that in less-diverse rotations.

Diversifying the corn–soybean rotation with cool-season crops will also accrue additional benefits for crop production. Adding small grain crops to the corn–soybean rotation can reduce root diseases of soybean (Noel and Edwards 1996) and corn rootworm (*Diabrotica* spp.) infestations in corn (Sutter and Lance 1991), as well as improve crop yield (Zhang et al. 1996).

Source of Materials

[1] Sigma Plot. Jandel Scientific, San Rafael, CA, 94901.

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